BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B69 05107

SUBJECT: Identification of Artifacts in a Time-Frequency Spectrogram
Case 320

DATE: May 29, 1969

FROM: L. A. Ferrara

ABSTRACT

Bands of constant frequency energy were displayed in many of the flight measurements processed while performing spectral analyses of the longitudinal oscillations (POGO) which occurred during Saturn V launch vehicle powered flight. Questions were raised concerning the identity of these constant frequency signals following an S-II stage POGO analysis presented by Mr. J. Z. Menard of Bellcomm to a recent Apollo Program Office 8:30 a.m. meeting.

This memorandum includes the results of an examination of the constant frequency signals which appear on time-frequency displays generated during spectrum analyses of Saturn V structural flight measurements. Possible sources of these artifacts are reviewed and remedial methods which could be used to reduce or eliminate them are discussed. Representative artifacts which were seen on the spectrograms of some flight measurements from the Apollo 9 mission are identified.

It has been found that the artifacts are normally constant in frequency and amplitude. They are displayed as vertical lines on the spectrogram. Artifacts are dark or light, continuous or broken depending upon their signal strength and whether or not other signals are present near that frequency and in the same time frame. Low order harmonics of strong signals (genuine or artifact) and their intermodulation products are often seen in the spectrograms.

Some of the possible sources of frequency artifacts are:

1. Induction or pick up from the AC power source in a ground data processing facility or airborne inverters.

2. Sampling rates from the telemetry system.

3. Frame synchronization pulses from the digital data code.

4. Tape speed variations in ground and airborne recorders.

(NASA-CR-106948) IDENTIFICATION OF ARTIFACTS IN A TIME-FREQUENCY SPECTROGRAM (Bellcomm, Inc.) 10 p

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MEMORANDUM FOR FILE

1.0 INTRODUCTION

In the course of processing approximately 100 measurements for spectral analysis of S-IC stage longitudinal oscillations on flights SA-501 and SA-502[1] and subsequent analysis of the longitudinal oscillations of the S-II stage on SA-504, frequency components were displayed which are not considered related to the vibrations of the launch vehicle. These frequencies are not produced by the structural dynamics of the vehicle and are considered in the general classification of artifacts. Some of these artifacts are induced by the onboard sensing, signal conditioning and telemetry equipment, and others are introduced by the ground data processing equipment.

This memorandum considers the sources of frequency artifacts and discusses the methods by which they can be produced and mixed with a bona fide signal. Artifacts which have been seen on some recent time-frequency displays of SA-504 flight measurements are identified and consideration is given to the methods appropriate to the reduction of artifacts.

2.0 ARTIFACT SOURCES

Sources of artifacts which can appear on the telemetry signal from a flight measurement are: (a) onboard timing system pulses, (b) pick up from AC power sources, (c) wow and flutter components from the onboard tape recorders (if data are stored before transmission to the ground station), (d) voltage transients caused by the sampling rate of the commutator (if the data are sampled) in a time division multiplex signal, (e) frame rates and subframe rates (if the analog signal is coded in a digital format), (f) calibration signals.

Anomalies in the equipment used to process the data from the measurement sensor to the final spectrogram have been known to produce artifacts. Of these some of the more prominent are:

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[1] Spectrum Analysis of Apollo 4 and Apollo 6 Data - Case 320, J. Z. Menard, Bellcomm Memorandum for File, Nov. 12, 1968.

Tape Speed Variation

In FM multiplex telemetry systems such as those used for the majority of the data analyzed, tape flutter or the short term periodic variation in tape speed, introduces frequency errors which can effectively modulate the desired signal with a false signal containing frequency components up to 3% (peak-to-peak) of the speed of the airborne recorder.* Tape flutter can also be introduced by the ground system tape recorder/reproducer but because of the size and greater mechanical precision of ground station recorders, the average flutter component is an order of magnitude less (about 0.3% peak-to-peak) than airborne recorders. In each case (ground and airborne recorders), short term speed variations can be virtually eliminated through good telemetry practices and use of a reference signal and tape speed compensation circuits which automatically remove the unwanted modulation from the signal due to tape speed variation. Only a few of the duplicated measurement tapes which were processed into spectrograms contained a reference signal. It has been assumed that tape speed compensation was used when available, in producing the duplicate tapes but artifacts from this source are always anticipated.

Instrumentation Tape Processing

Ground station processing equipment and tape duplicating facilities sometimes add unwanted signals. Of these, the most predominant is a 60 hertz frequency from the local power source which often appears on the magnetic tape duplicated on an instrumentation recorder. Also, system time codes, such as IRIG B, are usually added to a multitrack instrumentation tape at the ground station or data reduction facility. Occasionally, the timing signal is recorded at a maximum signal level and too high a signal level can result in tape "splatter" which causes some of the timing signal to appear on adjacent tracks of the instrumentation tape. IRIG "B" timing is rich in frequencies of 10 and 100 hertz as seen in Figure 1, which is a spectrogram of the timing signal from one of the SA-504 measurement tapes.

Spectrum Analyser Signature

The spectrum analysis equipment can not be overlooked as a source of introducing artifacts in the spectrogram. As a standard practice before and after any data analysis run, a low level Gaussian noise should be recorded on the instrumentation tape recorder associated with the analyzer. The low level

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* % peak-to-peak flutter = $\frac{\text{f max} - \text{f min}}{\text{fc carrier}} \times 100$

signal (slightly higher than the analyzer system threshold) is then played back into the system and written as a spectrogram. A system signature spectrogram of white noise recorded at a -40 dBv level is shown in Figure 2. This is the signature of the analyzer channel which was used to produce the 0-150 hertz spectrogram of the IRIG "B" timing signal shown in Figure 1.

3.0 ARTIFACT IDENTIFICATION

The majority of the artificial frequency products caused by an extraneous agency have one common characteristic; they are of constant frequency and usually relatively steady in amplitude. They appear as straight vertical lines (sometimes broken) on the spectrograms. With no other signal present, artifacts exhibit a fairly constant degree of blackness due to the stability of the Automatic Gain Control (AGC) circuitry of the spectrum analyzer. Signals, such as calibration marks, which appear on the tape before and after the measurement are identified by their constant frequency separation and the noticable change in background noise displayed on the spectrogram. In-flight calibration marks are of comparatively short duration and often do not even appear on the display. When they do, they appear as a string of evenly spaced horizontal dots due to the constant frequency of the calibration voltage switching.

In the presence of a strong signal, (artifact or genuine) the AGC of the analyzer supresses the background noise and other weak signals in the vicinity of the strong signal. In some cases, as with a strong 60 hertz artifact, the background signals are completely wiped out as evidenced by a band of white or light grey preceding the black 60 hertz mark.

Because of the sensitivity of the analyzer (it is designed to be optimum for low signal-to-noise ratio inputs), a strong complex waveform within the analyser pass band will usually produce harmonics. The second harmonic is often seen, some third harmonics and occasionally a fourth harmonic of a low frequency signal can be observed. A genuine signal will combine with an artifact (timing, 60 hertz power supply pickup, sampling rate transients, etc.) to produce the full band of intermodulation products. If the resultant signal is sufficiently large, the low order harmonics of the intermodulation products will also be present.

4.0 ARTIFACT EXAMPLES

Spectrograms of the Apollo 9 command module X, Y, and Z axes accelerometer measurements are shown in Figures 3, 4, and 5. These spectrograms exhibit fairly strong and steady frequency components every 10 hertz and are believed to be artifacts. They can be attributed to a combination of fundamental and beat frequencies as follows:

A. The analog voltage output from the accelerometers was sampled at 100 samples per second (therefore a 100 hertz component is mixed with the signal).

B. The signal was downlinked as part of a pulse code modulation digital signal with 50 subframes per second (therefore a 50 hertz component).

C. A strong 60 hertz signal was present on the tape.

Intermodulation products of these frequencies and their harmonics will yield artifacts every 10 hertz within the 0-150 hertz bandpass of the spectrum analyzer.

5.0 REDUCTION OF ARTIFACTS

Additional filters may be placed in the signal path before processing in the analyzer to reduce the effects of unwanted signals. This technique can be used effectively to reduce the amplitude of a moderately strong 60 hertz signal by setting a low pass filter with steep skirts (at least 18 dB attenuation per octave) at a cutoff frequency of 30 hertz. The penalty for this of course is that bona fide signals of interest in the 30 to 60 hertz region (and above) will also be attenuated according to the characteristics of the filter.

A better solution is to reduce or eliminate the artifact at the source before it appears on the tape track with the signal. Care in the adjustment of signal recording levels, processing equipment grounding techniques at the data reduction facilities, and the use of selective frequency rejection filters would do much to enhance the fidelity of the signal to be analyzed.

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L. A. Ferrara

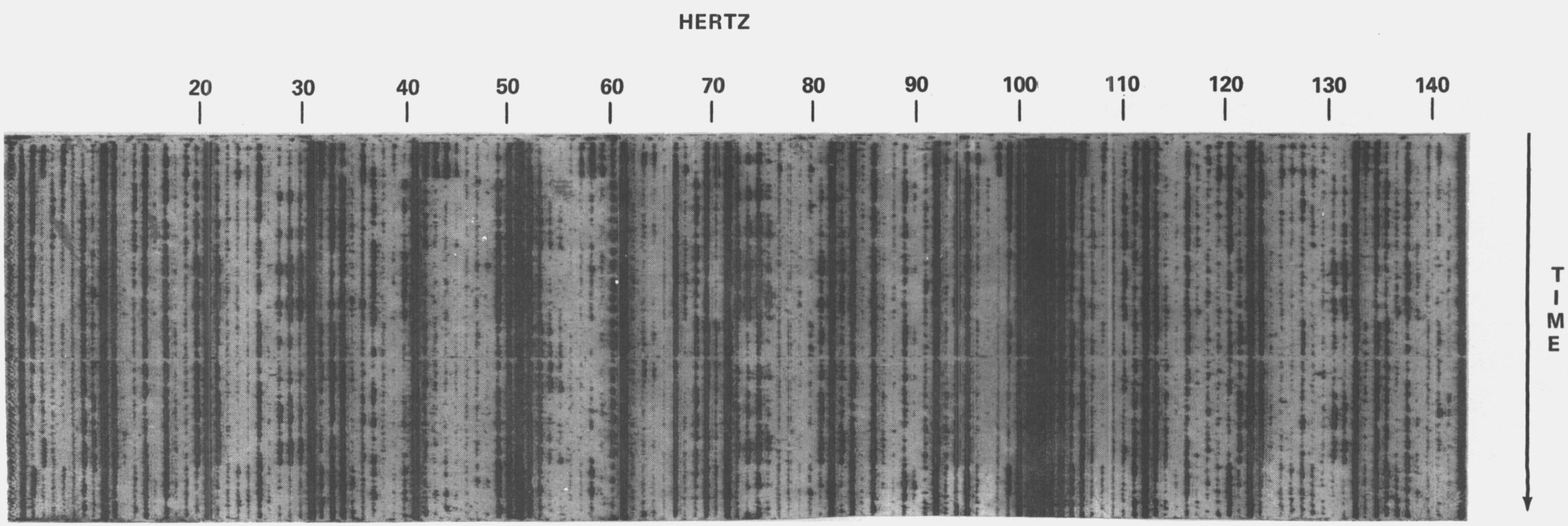

FIGURE 1 - SPECTRUM ANALYSIS OF 100 PPS TIME CODE

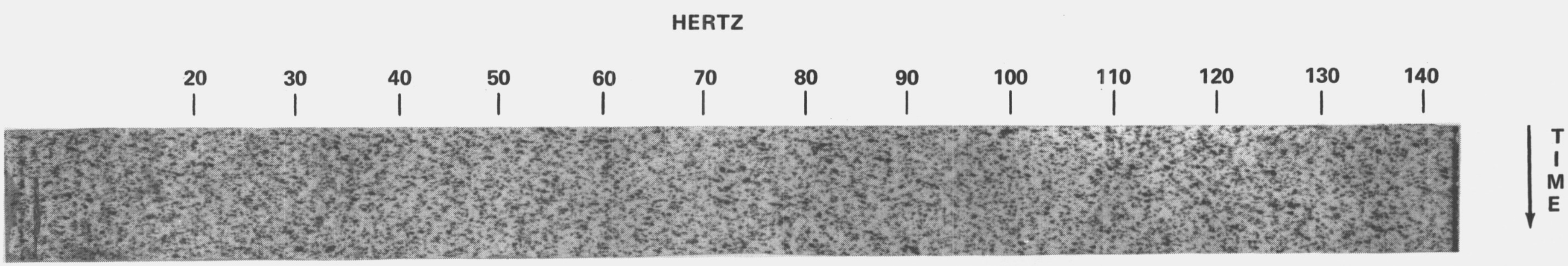

FIGURE 2 - SPECTRUM ANALYSIS OF WHITE NOISE (-40 dBV)

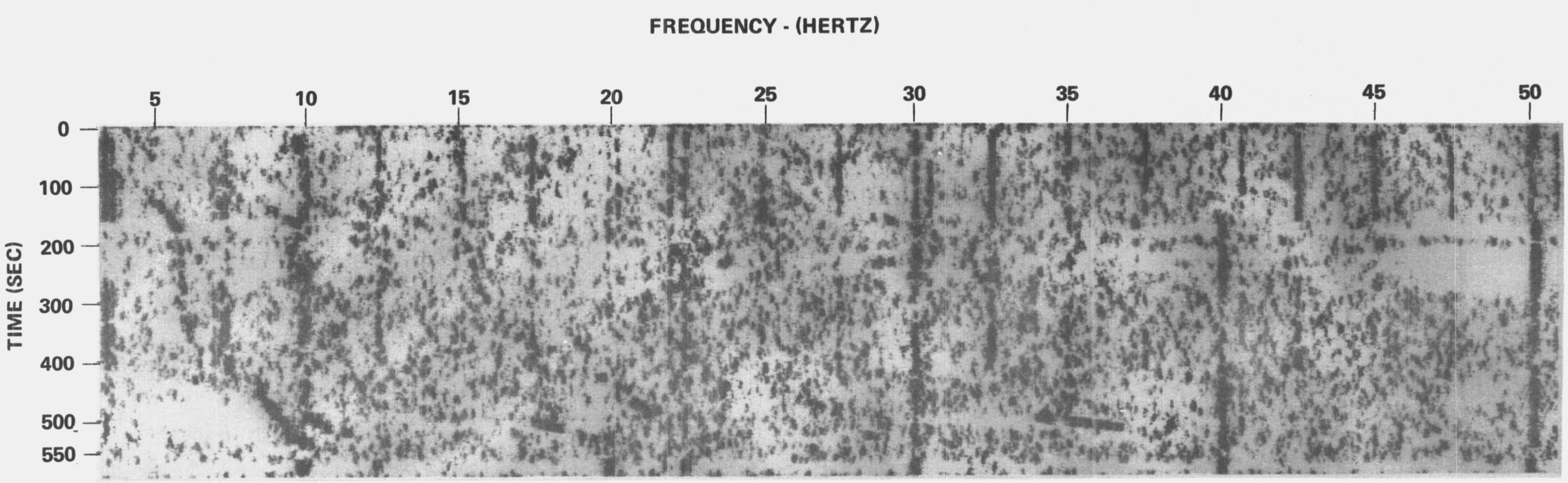

FIGURE 3 - AS-504 CM CK 0026A X-AXIS ACCEL

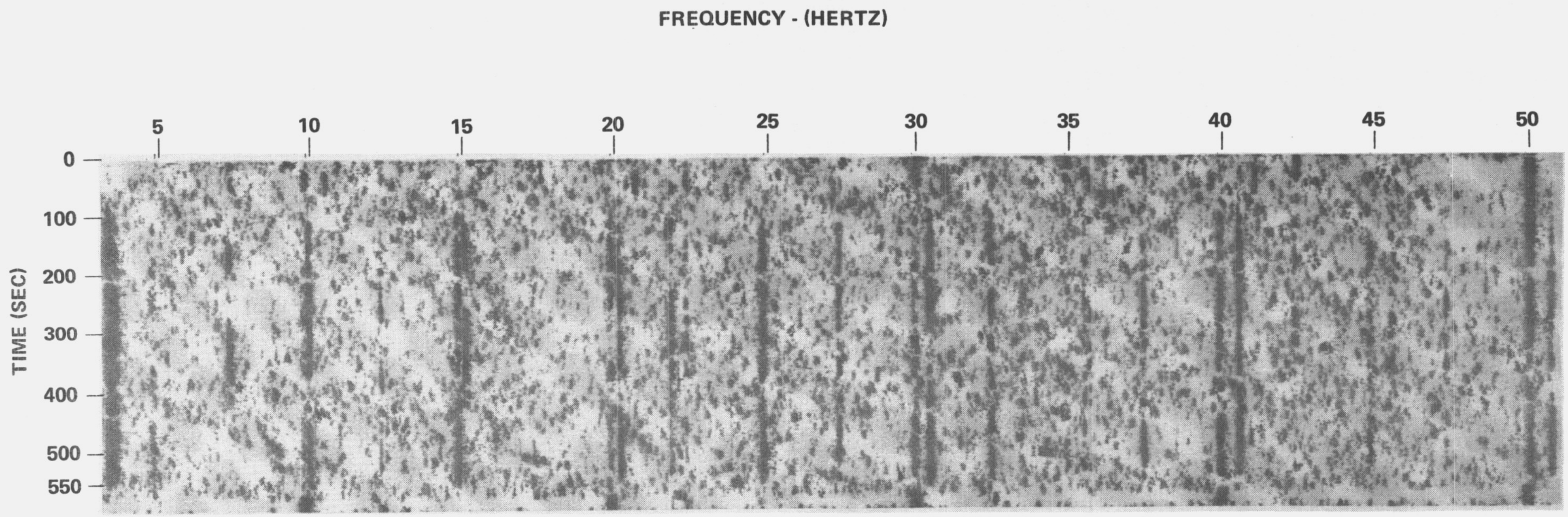

FIGURE 4 - AS-504 CM CK 0027A Y-AXIS ACCEL

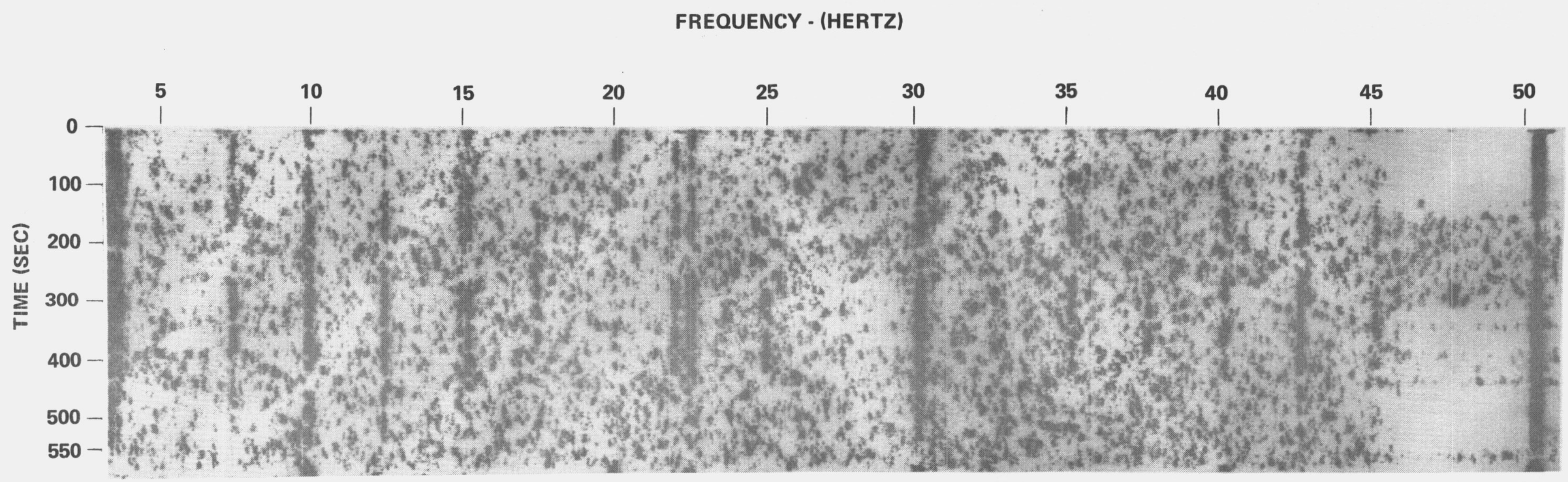

FIGURE 5 - AS-504 CM CK 0028A Z-AXIS ACCEL

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FROM: L. A. Ferrara, Jr.

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